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SUMMARIES OF ENGINEERING CONSULTANT STUDIES RELATED TO
LEAD PHASE-DOWN IN GASOLINE, 1983.

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**SUMMARIES OF ENGINEERING CONSULTANT STUDIES RELATED TO LEAD
PHASE-DOWN IN GASOLINE**

February, 1983



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The studies commissioned by Environment Canada are primarily technical in nature and consider a number of approaches to lead reduction in gasoline and their implications. It is to be emphasized that the findings, conclusions and recommendations of the consultants do not necessarily reflect the views of the Department. These studies will form the basis for a review of the socio-economic implications of reducing or eliminating lead in gasoline.

Summaries and tables of contents for the contract studies are provided. Interested parties may review the individual reports at any of the following locations:

Mrs. Henne Kahwa
Head, Reader Services
Departmental Library
Environment Canada
2nd Floor, Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec
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**INCREMENTAL COSTS TO THE REFINING INDUSTRY ASSOCIATED WITH THE
REDUCTION IN LEAD ANTIKNOCK USAGE IN GASOLINE***

December 1981

* This report was prepared for Environment Canada by MHG International Ltd., Toronto, under Supply & Services Canada Contract No. OSS 80-00169

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NOTE:

A separate volume (Appendix 1) containing all the computer simulation results complements this main volume.

The principal objectives of this study were to define the extra processing capacity and to estimate the associated incremental capital and operating costs which the 37 Canadian refineries would incur if lead additive levels in motor gasoline were progressively reduced from 1979 levels to zero, whilst retaining the octane quality.

To reflect the different crude diets and product slates prevalent throughout the provinces, Canadian refineries were segregated into four regions - Atlantic, Quebec, Ontario and Western. A process simulator (non-LP) was used to compute the process parameters and models were developed representing the four regional composite refineries. Reliance was placed on user interaction to optimize the process operations to attain approximate minimum crude oil throughputs, whilst retaining original product quantities and specifications.

It was deduced hypothetically that no capital investment would be required if 2 g/Igal and 1 g/Igal lead level controls were imposed. However, many individual refineries may detract somewhat from the 'average' refinery configuration used, and may necessitate some process unit modifications or changes in marketing strategy.

To conform to a zero lead level control, the model indicates that significantly more processing capacity would be required in all regions. The approach adopted in the study was one whereby existing process unit capacity would be utilized to the best extent possible and as such, extra process units would be confined to Catalytic Reforming, virgin naphtha (LSR) Isomerization and Alkylation. The associated incremental capital costs have been estimated to be approximately \$886 million Canadian on a 1979 basis.

The regional cost split is:

Atlantic	20%
Quebec	23
Ontario	29
Western	28

Product property specifications could be met with relative ease but the potential difficulties in the Quebec and Atlantic Regions are currently obviated by use of MMT to produce unleaded gasolines. Crude oil increments corresponding to the zero lead case are listed below, together with corresponding energy penalties:

	Crude Oil Increment %	Energy Penalty %
Atlantic	1.05	0.09
Quebec	1.51	0.34
Ontario	1.16	0.40
Western	2.26	0.82

Incremental operating costs were calculated based on the converted regular motor gasoline pool volume only in 1979 in each region and the results are shown below:

	2 g/Igal	Canadian cents/litre @ Control Level	
		1 g/Igal	No lead
Atlantic	0.20	0.43	2.52
Quebec	0.17	0.69	1.80
Ontario	-	0.03	1.37
Western	-	0	1.05

Projected construction schedules have been developed and a staggered four to five year program is recommended. Published future projects in the refinery and petrochemical industries will create constraints through skilled-trade construction labor shortages, and pipefitters are expected to be especially critical in the Western region.

It is considered that there will be many opportunities for refineries to specialize their markets to alleviate some of the constraining parameters induced when lead-free gasoline is produced. Essentially, they are categorized as 'premium gasoline' and 'diesel fuel' refineries. Refineries in remote locations are envisaged to incur the highest cost penalty to produce lead-free gasoline.

Regional variations in the gasoline/distillate ratio are marked and range from 0.64 in the Atlantic to 1.21 in the Western regions. This parameter in addition to the crude diet should be appreciated when evaluating the regional differences.

Brief discussions are included in the report on the following topics:

- future gasoline production to 1995
- heavy oil refining
- technological progress to produce high octane gasoline without the use of lead anti-knock additives.

The process capacity and cost estimates produced in this report should not be regarded as definitive, but should be interpreted in the light of serving to illustrate the directional trends which refiners might assess when demands for increasing proportions of lead-free gasoline are encountered. Also the study indicates potential strategies which refiners might adopt to alleviate known constraints.

**INCREMENTAL COSTS TO THE REFINING INDUSTRY ASSOCIATED WITH THE
REMOVAL OF LEAD ANTI-KNOCK ADDITIVE IN GASOLINE BASED ON PRODUCT
SPECIFICATIONS ISSUED BY THE CANADIAN GOVERNMENT SPECIFICATIONS
BOARD***

August 1981

* This report was prepared for Environment Canada by MHG International Ltd., Toronto, under Supply & Services Canada Contract No. OSS81-00077

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The principal objectives of this study were to define the extra processing capacity and to estimate the associated incremental capital and operating costs which the 37 Canadian refineries would incur if lead additive levels in motor gasoline were reduced from 1979 levels to zero, whilst retaining the octane quality.

To reflect the different crude diets and product slates prevalent throughout the provinces, Canadian refineries were segregated into four regions - Atlantic, Quebec, Ontario and Western. A process simulator (non-LP) was used to compute the process parameters and models were developed representing the four regional composite refineries. Reliance was placed on user interaction to optimize the process operations to attain approximate minimum crude oil throughputs, using product specifications issued by the Canadian Government Specification Board. The change to total lead-free gasoline mode of operations would entail installations of C5/C6 Isomerization units in Canadian refineries in all regions except Western. The total capital investment required was estimated to be \$64 million Canadian. The incremental annual operating costs totalled \$53 million and the incremental production costs based on the leaded regular gasoline portion ranged from 0.65 ¢/L in Atlantic region to -0.04 ¢/L in Western region. The energy penalties ranged from 0.31 to 0.50%.

Regional variations in the gasoline/distillate ratio are marked and range from 0.64 in Atlantic to 1.21 in Western region. This parameter in addition to the crude diet should be appreciated when evaluating the regional differences.

Brief discussions are included in the report on the following topics:

- future gasoline production to 1995
- heavy oil refining
- technological progress to produce high octane gasoline without the use of lead anti-knock additives.

ASSESSMENT OF THREE SCENARIOS FOR GASOLINE PRODUCTION IN CANADIAN REGIONS*

December 1981

* This report was prepared for Environment Canada by MHG International Ltd., Toronto, under Supply & Services Canada Contract No. OSS81-00090

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 - Computer Simulation Results

The energy penalties and additional process unit capacities necessary to achieve three control cases of motor gasoline production in Canada were defined using MHG's in-house computerized refinery process simulator. Composite refineries representing refineries in each of the Atlantic, Quebec, Ontario and Western regions were used based on the 1979 scenario and specific product specifications. Subsequently, three cases were investigated:

- Case A: Production of total leaded regular gasoline
- Case B: Production of total unleaded regular gasoline
- Case C: Production of total unleaded premium gasoline

The transition to Case A production results in a reduction in crude consumption, with no change to process units. This effect is induced by there being a net decrease in octane barrel demand.

The change to Case B production incurs energy penalties ranging from 0.38% in Ontario to 0.67% in Quebec. Isomerization capacity of 40557 BPCD would be required in Ontario, other regions remaining unchanged.

The change to Case C mode of operations would entail installation of C5/C6 Isomerization units in Canadian refineries in all regions, installation of HDS units in Ontario and Western regions, and new reformer units in all but the Western region. The associated energy penalties ranged from 0.77% in Atlantic to 1.97% in Ontario.

Conclusions reached were as follows:

- 1) As in the previous study, the thirty-seven oil refineries operating in Canada in 1979 were divided into four distinct regions, namely Atlantic, Quebec, Ontario and Western (Figure 2-3), to reflect the differences in crude diet and product slate in 1979 (Table 2-20). The regional split is as follows:

Atlantic 5;	Quebec 7;
Ontario 8;	Western 17;

The octane quality of the three basic grades of gasoline required in the base case and the corresponding lead additive usage is given below:

Grade	RON	Lead Levels in g Pb/lgal			
		Atlantic	Quebec	Ontario	Western
Leaded Regular	93.1	2.71	2.76	1.73	1.99
Unleaded Regular	92 (90 for Western)	0	0	0	0
Unleaded Premium	95 (93 for Western)	0	0	0	0

2) Incremental crude oil throughputs and associated energy penalties for the three control cases are summarized below:

	Incremental % Crude Throughputs	Energy Penalties %
<u>Case A (all LR)</u>		
Atlantic	-0.50	-0.15
Quebec	-0.82	-0.32
Ontario	-0.58	-0.08
Western	-0.42	-0.09
<u>Case B (all UR)</u>		
Atlantic	1.19	0.41
Quebec	1.82	0.67
Ontario	0.93	0.38
Western	0.49	0.46
<u>Case C (all UP)</u>		
Atlantic	2.53	0.93
Quebec	3.74	1.41
Ontario	5.06	1.97
Western (C-2)	1.61	0.77

- 3) Fuel gas productions are lower in Case A and higher in Cases B and C as a result of the difference in reformer severity. The increase in fuel gas availability in Cases B and C reduces the refinery own fuel oil consumption.
- 4) For Case A gasoline production, no extra processing capacities are required.
For Case B gasoline production, C5/C6 isomerization capacity of 40557 BPCD is required in Ontario.
For Case C gasoline production, the following process capacities are necessary:

	BPCD		
	Isomerization	HDS	Reformer
Atlantic	11351	-	49850
Quebec	22175	-	87050
Ontario	39373	19873	120900
Western (C-2)	36811	35891	-
Total for Canada	109710	55764	257800

**RECALCULATION OF ENERGY PENALTY VALUES FOR VARIOUS SCENARIOS OF
GASOLINE PRODUCTION***

June 1982

* This report was prepared for Environment Canada by MHG International Ltd., Toronto, under Supply & Services Canada Contract No. 51SS. KE145-2-0072.

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- B CALCULATIONS OF ENERGY PENALTY FOR LEAD-FREE GASOLINE BASED ON PRODUCT SPECIFICATIONS ISSUED BY CANADIAN GOVERNMENT SPECIFICATIONS BOARD.
- C CALCULATIONS OF ENERGY PENALTY FOR THREE SCENARIOS OF GASOLINE PRODUCTION

As part of its ongoing efforts to improve the quality of the Canadian environment, the Environmental Protection Service of Environment Canada wished to determine the effects upon the petroleum refining industry of reducing the quantity of lead antiknock additives in motor gasoline.

MHG International was commissioned to undertake three related studies, the principal objectives of which were to define the extra processing capacity required across Canada for various gasoline production schedules and with various amounts of lead antiknock additive removed. In addition to requiring extra processing capacity, the removal of lead antiknock additive from gasoline, while at the same time retaining its octane rating, requires the processing of additional crude oil for the same quantity of gasoline produced.

The energy penalty for removing lead antiknock additive as defined by Environment Canada took credit for all additional fuels made as a consequence of processing the additional crude oil regardless of whether there was a market for the additional fuels or not. As a result of extensive reviews, Environment Canada has decided to redefine the energy penalty. This report presents new energy penalty figures as an addendum to the following three previously issued reports:

1. Incremental Refinery Construction Costs Associated with the Reduction in the Amount of Lead Additive in Gasoline.
DSS File No: 37SS. KE204-0-0510
MHG Reference: FED-831
2. Incremental Costs to the Refinery Industry Associated with the Removal of Lead Anti-knock Additive in Gasoline Based on Product Specifications Issued by the Canadian Government Specifications Board.
DSS File No. 40SS. KE204-1-0201
MHG Reference: FED-847
3. Assessment of Three Scenarios for Gasoline Production in Canadian Regions.
DSS File No. 40SS. KE204-1-0201
MHG Reference: FED-852

As part of the ongoing efforts to ensure the safety and security of the United States, the Department of Homeland Security is committed to the protection of the nation's infrastructure. This includes the identification and mitigation of potential threats to critical systems and the implementation of measures to enhance resilience and recovery capabilities.

The Department is currently conducting a comprehensive review of the nation's infrastructure, with a focus on the identification of vulnerabilities and the development of strategies to address them. This review is being conducted in a systematic and thorough manner, taking into account the unique challenges posed by different types of infrastructure and the potential for cascading failures. The results of this review will be used to inform the development of policies and programs to enhance the resilience and security of the nation's infrastructure.

In addition to the ongoing review, the Department is also working to enhance the resilience and security of the nation's infrastructure through a variety of other measures. These include the implementation of standards and best practices for the design and construction of critical systems, the development of emergency response plans, and the establishment of a national infrastructure security center. The Department is committed to ensuring that the nation's infrastructure is able to withstand and recover from a wide range of threats, including natural disasters, cyberattacks, and terrorism.

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**A STUDY ON THE INCREMENTAL CAPITAL AND OPERATING COSTS TO THE LEAD
ANTIKNOCK MANUFACTURERS ASSOCIATED WITH THE REDUCTION IN LEAD
ANTIKNOCK USAGE IN GASOLINE***

May 1981

* This report was prepared for Environment Canada by MHG International Ltd., Toronto, under a Supply & Services Canada Contract No. OSS80-00169.

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- A QUARTERLY ANALYSES OF LEADED GASOLINE PRODUCTION FOR 1979 BY REGION AND REFINERY.
- B CALCULATIONS OF OPERATING COSTS.
- C TERMS OF REFERENCE

This report has been prepared for the Environmental Protection Service, Environment Canada, and consists of a study on the incremental capital and operating costs which would be incurred by the Canadian manufacturers of lead anti-knock additives in the event that the quantity of such additives permitted in gasoline is reduced from its present maximum of 3.5 grams of lead per imperial gallon.

There are, in Canada, two manufacturers of lead anti-knock compounds, namely DuPont Canada Inc. with a plant at Maitland, Ontario, and Ethyl Canada Inc. with a plant near Sarnia, Ontario. These two companies have a total capacity of approximately 100 million pounds of lead additive per year but are presently estimated to be operating at only about 66% overall capacity.

Based upon past records of the usage of leaded and lead-free gasoline, the average lead contents and upon forecasted demands, it has been possible to make some predictions of the future requirement for lead antiknock additive to the year 1995. The study shows that the demand for this additive is expected to decline quite markedly over this period of time.

The effect of this decline, and also of three levels of control on the lead content of leaded gasoline have been studied. The financial impact of reduced production upon each of the two Canadian manufacturers has been examined.

Conclusions reached were as follows:

- (i) A major conclusion of this study is that the shift to lead-free gasoline has already put in motion a process which will reduce the consumption of lead antiknock additive to about half its 1979 level by the early 1990's. The demand for lead antiknock additive in 1981 is expected to be such that Ethyl Canada alone has the capacity to satisfy.
- (ii) Regulatory control at the 2 g Pb/Igal level during 1979 would have resulted in a reduction in lead additive consumption of about 22%; however, with appropriate reductions in operating staff, both manufacturers could have remained profitable albeit at lower operating margins.
- (iii) Regulatory control at the 1 g Pb/Igal level during 1979 would have resulted in a reduction in lead additive consumption of about 56%, and would have permitted either manufacturer alone to satisfy the demand. Using the 1979 average selling price for lead additive, it is estimated that DuPont Canada would not have been able to maintain a profitable operation and that Ethyl Canada's operating revenue from

its lead additive business would have been reduced to about one fifth of the estimated actual.

- (iv) A total ban on lead in gasoline would result in a large expenditure amounting to about Cdn \$5-6 million for decommissioning of the two manufacturing facilities and the approximately 120 tank cars and trucks dedicated to lead antiknock service.

**ASSESSMENT OF ENERGY PENALTY FOR THE PETROLEUM REFINERIES FOR THE
PRODUCTION OF LEAD-FREE MOTOR GASOLINE***

March 1981

* This report was prepared for Environment Canada by MHG International Ltd., Toronto, under Supply & Services Canada Contract No. 4 DSS. KE204-0-0407.

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6. PROCESS VARIABLES IN REFORMING AND CRACKING OPERATIONS
7. DISCUSSION OF RESULTS
8. CONCLUSIONS
9. REFERENCES
10. APPENDICES

The change in refinery operations necessary to effect totally lead-free gasoline pools in the Quebec Region of Canada, based on 1979 data, will entail an increase in catalytic reforming throughput, the extent of which will vary with the gasoline pool octane quality desired and the maximum severity at which existing units can operate on a long term basis. Additionally for the higher octane pools, C_5/C_6 isomerization unit capacity will be required equivalent to 4.4% of crude oil throughput. Other refinery process units are capable of coping with the lead-free gasoline mode of operations.

Several case studies were performed to observe the effect of assigning different process parameters. Two specific unleaded regular gasoline pool octane numbers - 93.6 and 91.5 RON were investigated; also the reformer severity was set at both 100 RON and 103 RON. (See overleaf for summary of key results).

The Gasoline:Distillate ratio for Quebec in 1979 was 0.92 and regular leaded gasoline represented 54% of the motor gasoline pool and averaged 93.1 RON using $3.1 \text{ cm}^3 \text{ Pb/Igal}$.

If the leaded regular gasoline was replaced by 93.6 RON unleaded, the incremental crude oil throughput would be 8.5%, when operating the reformers at 100 RON severity. This would incur incremental reformer throughput amounting to 60%. However, these figures would decrease to 1.89% and 26% if the reformers operated at 103 production would need to be increased to satisfy distillate product specifications, consistent with producing the same distillate product quantities.

When the unleaded regular gasoline pool is lowered to 91.5 RON, the incremental crude oil demand would vary from 0.48% to 1.25% with and without the use of isomerization units respectively, for a reformer severity of 100 RON. Associated incremental reformer throughput would increase to 52% from 8.4%.

The capability of existing catalytic reforming units to operate continuously at high severities in excess of 100 RON will vary with each unit and will depend on the original process/mechanical design concepts. The feasibility of revamping these units is briefly discussed in the text, aside from using technologically advanced bimetallic catalysts. Downrating of design capacity of existing reforming units is a real possibility.

The net energy penalty as defined in this study, amounts to less than 0.6% for all case studies. Coke production in the FCC unit and variation in estimated heating values of Heavy Fuel Oil product and crude oil will influence the results significantly.

The conclusions of this report are derived from the development of a non-LP computer model of a composite refinery representing the operations and process plant configurations of refineries in the Quebec Region of Canada. It should be recognized that the crude oil from increments, energy penalties and associated capital costs, will vary from one region to another. The effects of crude oil diet, product slate, process unit configuration, gasoline to distillate ratio, etc., applicable to refineries in other parts of Canada may lead to different conclusions.

Of particular relevance is the difficulty experienced during the simulations of maintaining the physical property specifications of products other than motor gasoline.

Finally, it should be appreciated that the composite refinery model used in the study may be atypical of operations existing within specific refineries in the Quebec Region, due to probable variations in crude diet, process unit configuration and with special emphasis on seasonal variations in product slates and qualities. However, the study serves to illustrate the directional effects of numerous parameters which Quebec refinerers should assess to effect a totally lead-free gasoline pool.

A summary of the principal results follows.

SUMMARY OF RESULTS

	Reformer Severity RON	Isomerization Unit Inclusion	Crude Oil Rate BPCD	Crude Throughput Increment %	Heavy Fuel Oil Production Increase %	Unleaded Regular Gasoline Quality RON	Energy Penalty %
Case 1 (Base Case)	98	No	508020	0	0	93.1 (Reg. Leaded) 93.6	---
Case 2	100	Yes	551404	8.54	31.2	93.6	0.48
Case 3	103	Yes	517616	1.89	0	93.6	0.42
Case 4	100	Yes	510440	0.48	0	91.5	0.06
Case 5	100	No	514343	1.25	0	91.5	0.59

**ASSESSMENT OF THE ECONOMIC IMPACT ON THE AUTOMOTIVE PARTS/SERVICE
INDUSTRY OF PROPOSED GASOLINE LEAD CONTENT REGULATIONS***

March 31, 1981

* This report was prepared for Environment Canada by Hickling-Partners Inc., under a Supply & Services Canada contract.

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The goal of this report is to estimate the extent and nature of the economic impact on the automotive parts and service industry of regulations lowering the allowable lead (tetraethyl lead) content in gasoline. The study addressed only the regulatory option of complete elimination of lead as engineering data indicated that no measurable change in servicing requirements would occur if even low levels of lead were present in gasoline.

For the purposes of estimating the timing and size of potential effects, two promulgation schedules were used. The first assumed a January 1983 starting date while the second used January 1985 as the initial date. In both cases, the economic impacts were measured as a change from the current regulatory baseline. The estimates were made for all-Canada and British Columbia. British Columbia was assessed individually because the market impacts appear to be largest in that province due to its older vehicle population.

Operating Cost Differences

In order to develop estimates of the effect that the removal of lead (TEL) has on the maintenance requirements and costs, an analysis of various measures of the effect was undertaken.

Firstly, a review of the historical test fleet data was undertaken. The studies reviewed were carried out in the late 1960's through to the early 1970's and indicated that significant maintenance improvements were possible for spark plugs and exhaust systems. A tabularized summary of the results of these studies is given in Figures 1 and 2. These studies indicated that unleaded gasoline:

- decreased spark plug replacement by 26-49%;
- decreased exhaust system (muffler) failure by 49-96%; and
- no other vehicle system or parts were significantly affected.

The second analytical approach used to estimate maintenance effects was to develop a time series of manufacturers recommended servicing requirements for leaded and unleaded vehicles. For this work, information on the top six manufacturers' recommendations was assembled for 1972-1981 model vehicles. This data indicated that only spark plugs change intervals were different between the two fuel types. Although oil change intervals were analyzed, most manufacturers (except Chrysler) did not recommend different "drain" intervals due to the use of unleaded fuel. The time series analysis (Figures 3 and 4) indicated significant reductions in maintenance requirements for

FIGURE 1 SUMMARY OF SPARK PLUG SERVICE LIFE DIFFERENCES

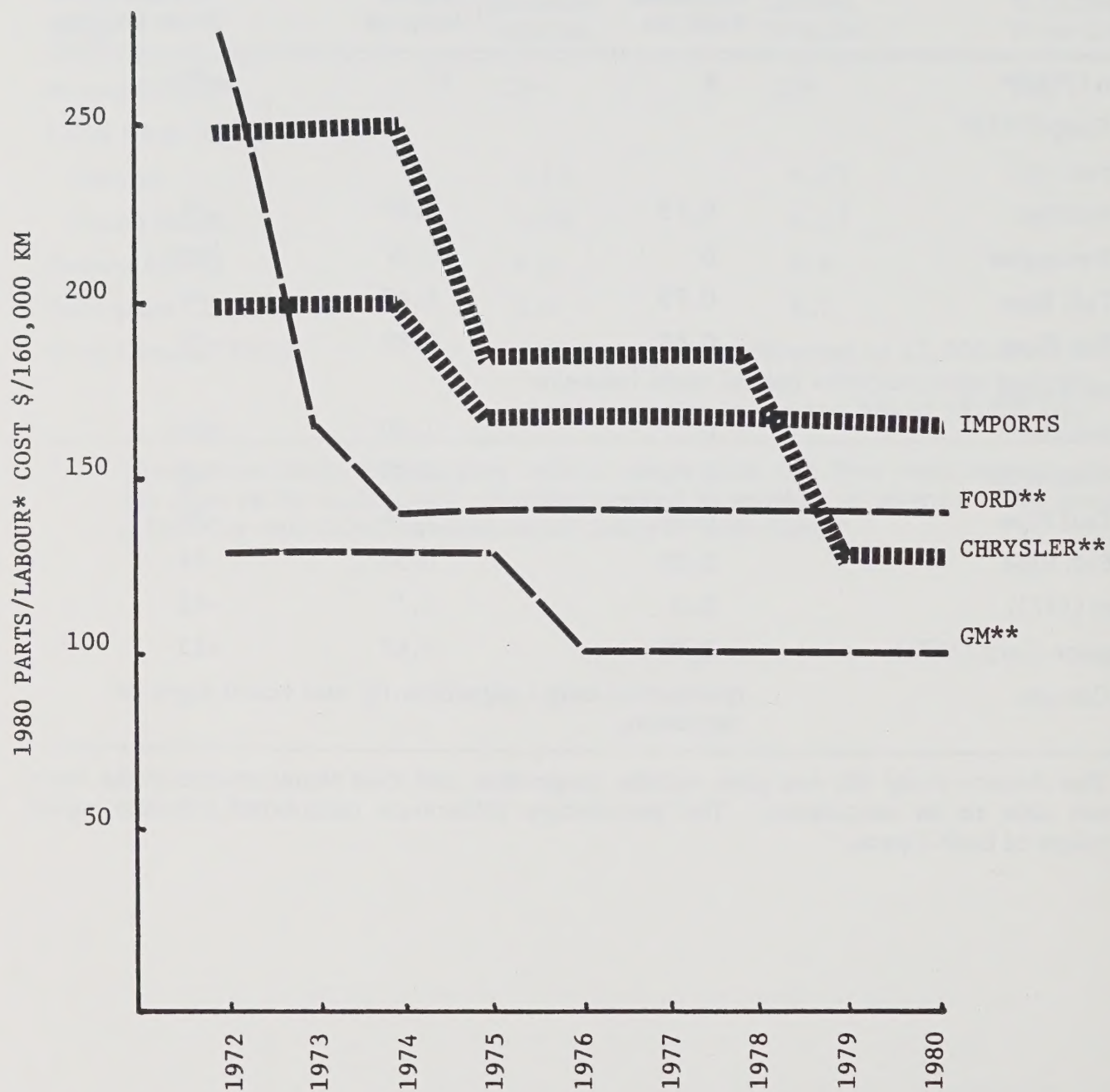
Study	Reported Effect (Changes/160,000 km)		
	Unleaded Vehicles	Leaded Vehicles	% Differences From Leaded
Amoco (1972)*	12*	23*	-48
Ethyl Corp (1972)			
Detroit	3.15	4.72	-33
Baton Rouge	4.00	6.15	-35
Dupont (1971)	4.9	6.6	-26
Aerospace Corp (1971)	3.4	6.7	-49
Shell Canada (1971)	- spark plugs still operating at 62,000 km with unleaded when leaded vehicles plugs typically have a maximum service life of 19,000 km.		

* The Amoco study did not give vehicle usage data and thus replacement rates were not able to be calculated. Number quoted in number of events. The percentage difference calculated assumes equal usage of both fleets.

FIGURE 2 SUMMARY OF EXHAUST SYSTEM SERVICE LIFE DIFFERENCES

Study	Reported Data (No. Replacements/160,000 km)		
	Unleaded Vehicles	Leaded Vehicles	%Differences From Leaded
Amoco (1972)*	8	37	-79
Ethyl Corp (1972)			
Detroit			
Muffler	0.75	1.47	-49
Resonator	0	0.27	high
Tail Pipe	0.79	1.47	-46
Exh Pipe	0.66	0.89	-26
Baton Rouge			
Muffler	0	1.50	high
Resonator	0	0.29	high
Tail Pipe	0.04	1.14	-96
Exh Pipe	0.04	0.32	-88
Dupont (1971)	0.3	1.7	-82
Aerospace Corp (1971)	0.29	1.67	-83
Shell Canada	qualitative only - significantly less visual signs of corrosion.		

* The Amoco study did not give vehicle usage data and thus replacements rates were not able to be calculated. The percentage difference calculated assumes equal usage of both fleets.



*Avg. costs based on dealer, specialist and mass retailer data.
 **Assumes a 6 cylinder engine.

FIGURE 3 OIL AND OIL FILTER HISTORICAL CHANGE IN MAINTENANCE REQUIREMENT (RECOMMENDED SCHEDULE)

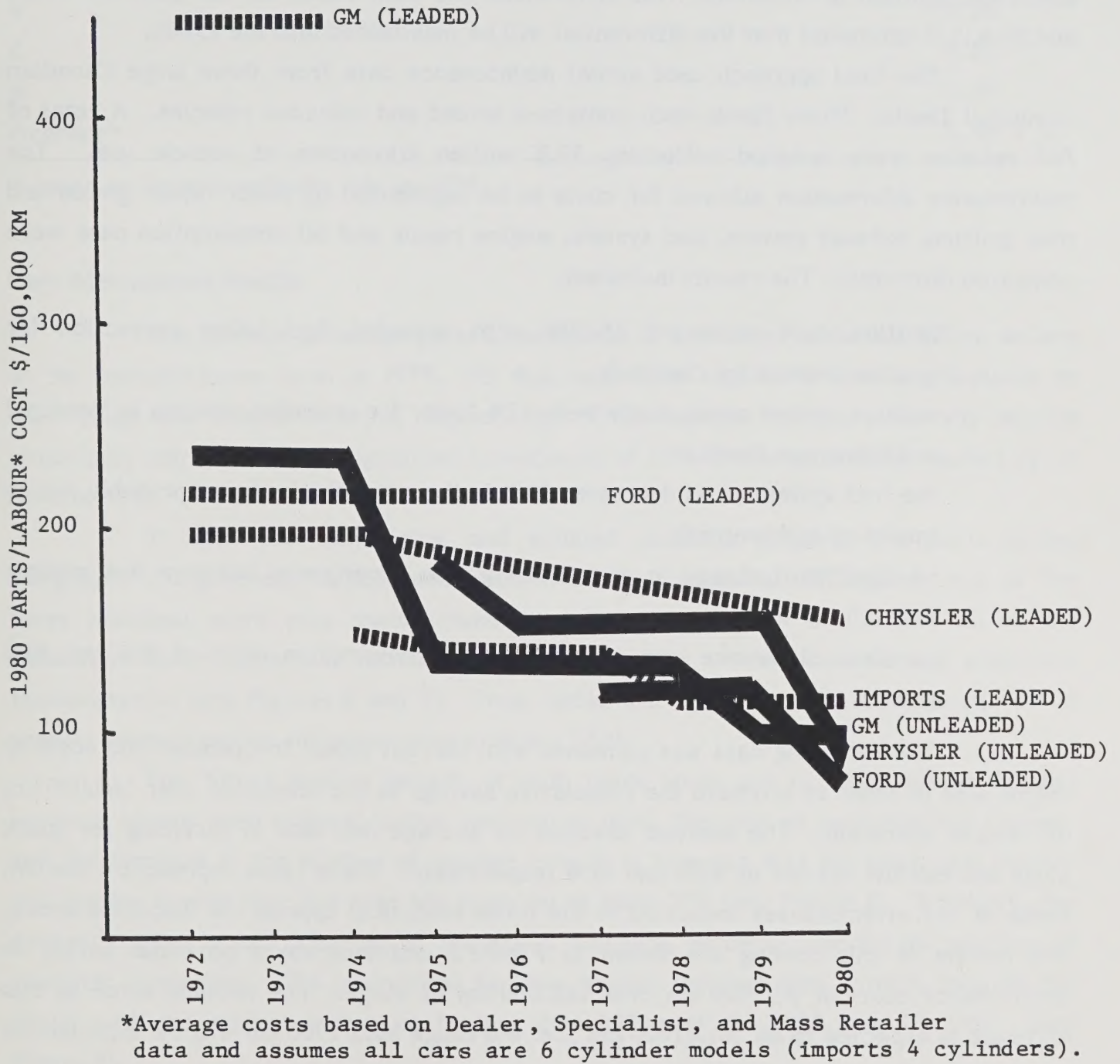


FIGURE 4

SPARK PLUGS HISTORICAL CHANGE IN MAINTENANCE
REQUIREMENT (RECOMMENDED SCHEDULE)

both spark plugs and oil over the last 8 years (in the order of 50-60% for both spark plugs and oil). Based on currently recommended maintenance schedules, the use of unleaded fuel decreases the spark plug replacement requirements by 40-50% (after the effect of electronic ignition is removed). This differential has been stable for the past few years and thus it is estimated that the differential will be maintained into the 1980's.

The final approach used actual maintenance data from three large Canadian municipal fleets. These fleets each contained leaded and unleaded vehicles. A total of 765 vehicles were sampled reflecting 32.8 million kilometers of vehicle use. The maintenance information allowed for costs to be segmented by major repair groups and thus ignition, exhaust system, fuel system, engine repair and oil consumption data were compared discretely. The results indicated:

- ignition cost decreased 25-30% with unleaded fuel (after correction for ignition technology changes);
- exhaust system repair costs were 42% lower for unleaded vehicles in Montreal and Edmonton fleets;
- the fuel system costs decreased 24% in the new vehicles (most probably due to improved carburetors);
- no significant change in engine repair was experienced between fuel groups; and
- no clear difference was seen in the oil consumption rates of the two fuel groups.

The foregoing data was combined with current repair frequencies and costs by engine size in order to estimate the cumulative savings to the consumer over 160,000 km of vehicle operation. The analysis assumed an average decrease in servicing for spark plugs and exhaust system of 40% and 47% respectively. These rates represent a median value of the effectiveness measured in the three analytical approaches discussed above. The results of this costing are shown in Figure 5 and indicate a potential saving in maintenance costs of \$1/1000 km over 160,000 km of usage. The nominal error on this estimate is expected to be \$0.5/1000 km (i.e. the range \$0.5/1000 km will be experienced by 60-75% of the vehicle population).

FIGURE 5 UNLEADED MAINTENANCE SAVINGS OVER 160,000 km

No. of Cylinders	\$/1000 km
4	0.80
6	0.88
8	1.09
Average*	0.99 $\approx$ \$1

* based on Ontario cylinder mix in 1979

Part Aftermarket Profile

The current Canadian parts aftermarket is estimated to be 1.2 billion dollars at the manufacturers level in 1979. Of this, only 4.2% and 7.7% were attributable to spark plugs and exhaust systems, respectively. Thus, because these are the only sectors potentially affected by the regulation a maximum of 12% of the total parts market could be affected.

In both the spark plug and exhaust products sectors, the participating companies are generally large diversified American companies. While only one of the three principal spark plug manufacturers maintains production in Canada, all of the exhaust products companies manufacture in Canada due to the economics of scale and transportation (see Figures 6 and 7). Thus, while spark plug manufacturing employs 400 people, exhaust system manufacturing employs 1210.

The future market growth of both spark plugs and to some extent exhaust products is poor even without further removal of lead. Because of technological changes and the increase in the number of smaller cars, it is forecast that the spark plug market will decline in size over the next ten years by at least 20% (see Figure 8). Similarly, the exhaust market is still adjusting to changes in fuel type, materials and the introduction of catalytic converters. The projections for this market indicate slow growth through the 1980s with the market increasing by less than 10% over the 1980 level by 1990. (see Figure 9).

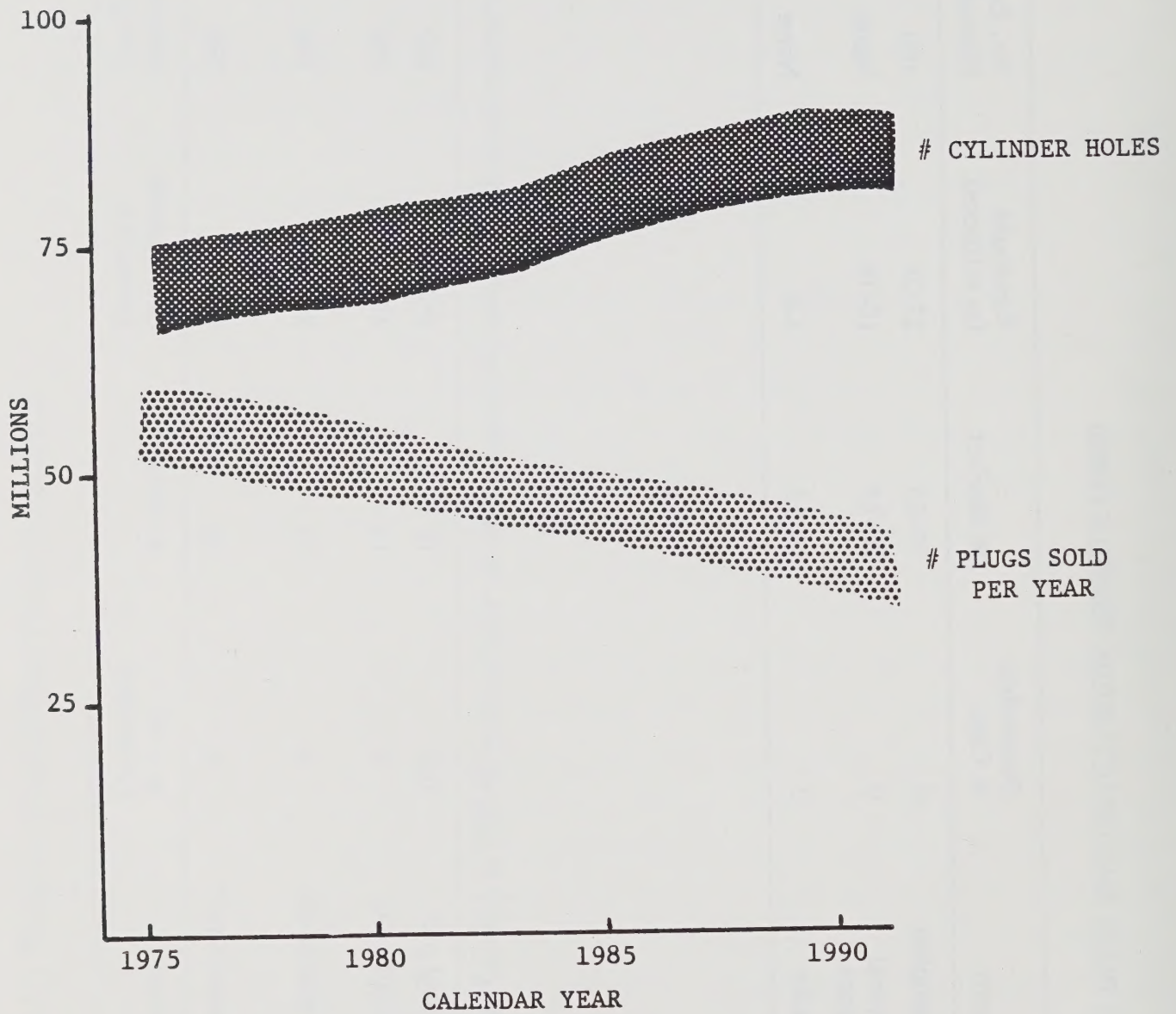
FIGURE 6 EXHAUST PRODUCTS MANUFACTURERS PROFILE

Company	Parent	Ownership % Can.	% Market	Revenues (in millions)	No. Employees (Manufacturing)	Plant
Walker Exhaust	Tenneco Inc.	0	50	40-45	350	Toronto
International Parts	IC Industries	0	25	20-25	250	Galt
AP Parts	Questor Inc.	0	15	12-14	260	Toronto
Thrush Inc.	Thrush Inc.	100	10	4-5*	350	Toronto

* Total production in Toronto is \$30-40 million/year of which approximately 85-90% is for export.

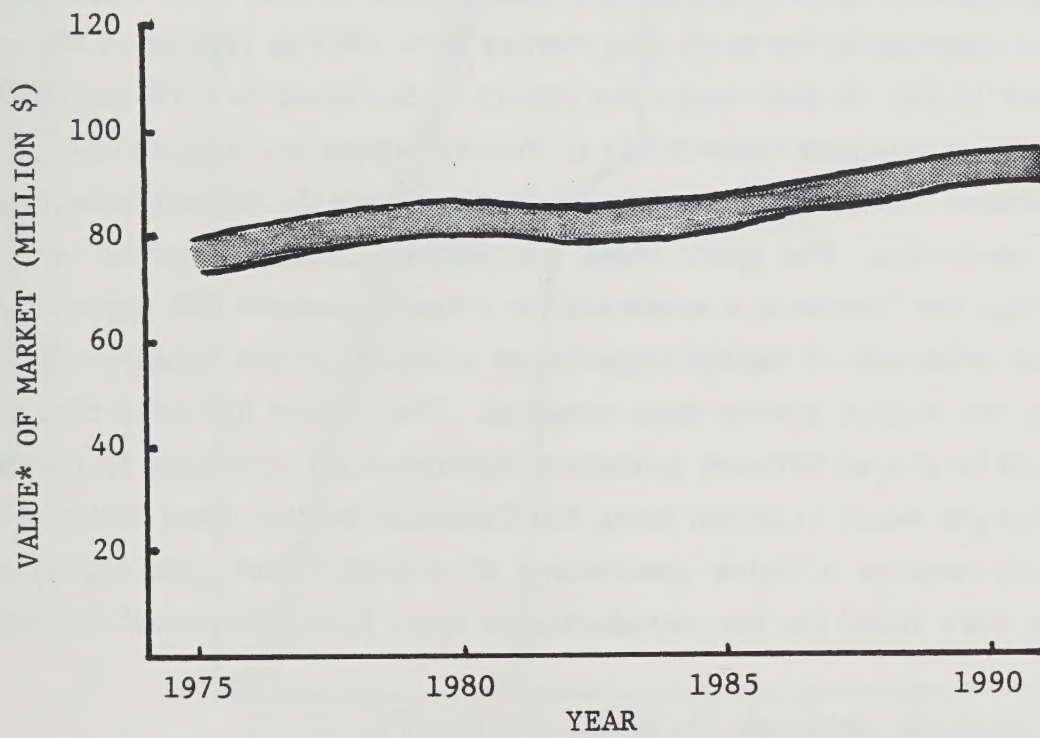
FIGURE 7 SPARK PLUG MANUFACTURERS PROFILE (1980)

Company	Parent	Ownership % Can.	% Market	Revenues (in millions)	No. Employees (Manufacturing)	Plant
Champion	Champion	0	55-65	27-36	400	Windsor
AC Division	General Motors	0	20-25	10-14	None	None
Autolite	Bendix	0	10-15	5-8	None	None



SOURCE: STUDY ESTIMATES

FIGURE 8 FORECAST OF CANADIAN SPARK PLUG MARKET SIZE



* at lowest selling price

FIGURE 9 CANADIAN EXHAUST SYSTEM MARKET

Impact Assessment

The impact of the proposed regulation was assessed by developing estimates of the vehicle population potentially affected by the decrease in market size that results and an assessment of the impacts by manufacturer and channel of distribution.

In order to forecast the numbers of vehicles which would be affected (only those that would change from leaded to unleaded gasoline) an analysis of the current Canadian vehicle population was undertaken. Based on the historical fuel requirements of new cars (see Figure 10) and the age distributions of vehicles in Canada and British Columbia, penetration estimates of unleaded vehicles (both tolerant and required) were forecast to 1990 (see Figure 11). Using these estimates and the data on the maintenance effectiveness of switching to unleaded fuel, projections of the impact on the spark plug and exhaust products markets to 1990 were made (see Figures 12 and 13). These data indicated a cumulative decrease in the spark plug market from 1983 to 1990 of 11.9% and for the exhaust market 16.5%. In both cases, the impact is decreased to 9.5% and 14.8% for spark plugs and exhaust products respectively if the regulations are initiated in 1985. The analysis also indicated that British Columbia would experience the highest impact due to its older vehicle population. For spark plugs, the British Columbia market impact would be 10% higher than for Canada as a whole and for exhaust products 13% higher.

Using these estimates of market impacts, an appraisal of the industry effects was undertaken using the market profile data compiled. The results indicated that the market decrease should be shared between producers approximately according to market share and that the changes would in effect bring the Canadian market more in line with the U.S. market which requires a higher percentage of unleaded fuel. No significant financial implications were found for the manufacturers apart from the overall decrease in revenues.

The labour impacts estimated are shown in Figure 14.

The principal spark plug firm affected would be Champion Spark Plug Co. while all exhaust manufacturers would be affected in proportion to sales. The exception to this is Thrush Inc. who would lose relatively few jobs due to its strong export position.

The impact of the regulation at the retail level was inferred from market intelligence on market shares, vehicle type and average revenue per facility. The conclusions of this analysis are given in Figure 15. For spark plugs, the most sensitive

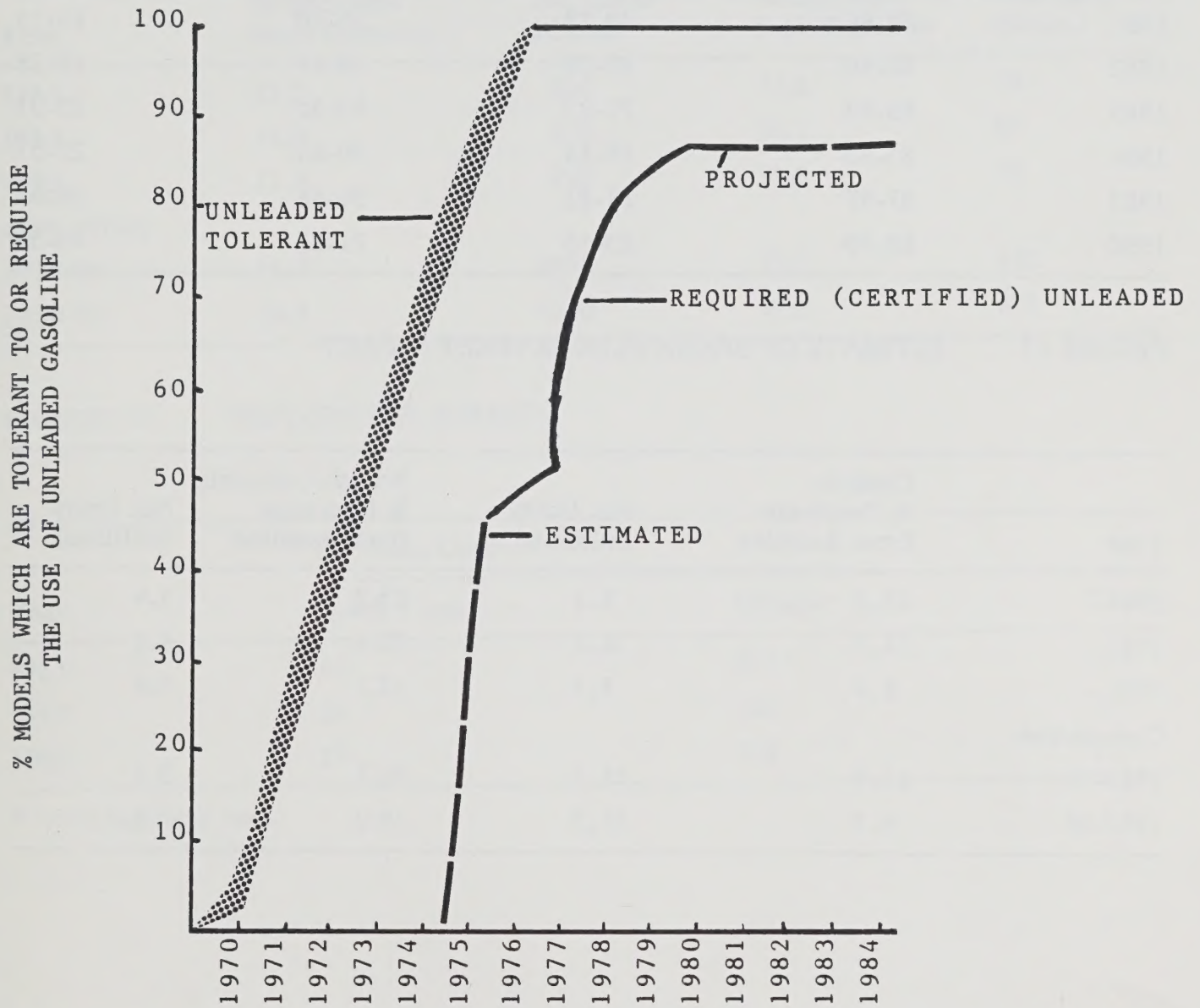


FIGURE 10 HISTORICAL MARKET PENETRATION OF UNLEADED VEHICLES

FIGURE 11 ESTIMATED MARKET PENETRATION OF UNLEADED VEHICLES

Year	Unleaded Tolerant (%POP)		Unleaded Required (%POP)	
	Canada	B.C.	Canada	B.C.
1981	76-86	63-73	30-40	14-24
1982	80-90	69-79	39-49	18-28
1983	83-93	75-85	45-55	23-33
1984	85-95	78-88	50-60	27-37
1985	87-97	81-91	56-66	31-41
1990	88-99	85-95	71-81	43-53

FIGURE 12 ESTIMATE OF SPARK PLUG MARKET IMPACT

Year	Canada		British Columbia	
	% Decrease from Baseline	No. Units (millions)	% Decrease from Baseline	No. Units (millions)
1983	17.5	8.2	25.2	1.4
1985	13.7	6.2	22.4	1.2
1990	8.4	3.5	18.2	0.9
Cumulative				
1983-90	11.9	38.7	21.7	8.1
1985-90	9.5	24.3	19.0	5.8

FIGURE 13 ESTIMATES OF EXHAUST SYSTEM MARKET IMPACT

Year	Canada		British Columbia	
	% Decrease from Baseline	No. Units (thous.)	% Decrease from Baseline	No. Units (thous.)
1983	23.5	400	33.8	70
1985	18.3	320	30.1	60
1990	11.3	220	24.4	50
Cumulative				
1983-90	16.5	2070	29.2	420
1985-90	14.8	1350	27.3	270

FIGURE 14 EMPLOYMENT IMPACTS

Year	Net Jobs Loss*		
	Spark Plugs	Exhaust	Total
1983	65	213	278
1985	50	166	216
1990	27	102	129

* from baseline case.

FIGURE 15 RETAIL LEVEL IMPACTS RANKINGS

Part Sector	Impact Level
	Least ----- Highest
Spark Plugs	Dealers (Domestic)
	Mass Retailers
	Independant Garages
	Dealers (Foreign)
	Service Stations
Exhaust Products	Service Stations
	Garages
	Dealers
	Mass Retailers
	Specialty Shops

channel is the service stations which gain much of their revenue from tune-up work. In exhaust products, the specialty shops will feel the highest effect.

It is important to note that at the retail level, the ability to diversify and thus avoid revenue drops, is related to the availability of investment capital. For this reason, the small service station or garage is perhaps the most vulnerable due to their low capitalization. On the other hand, the car dealers and specialty shops may be better able to cope with the changes due to their greater financial and managerial resources.

In summary, the impacts of the proposed regulations would appear to be significant but smaller than the impacts which will be imposed due to other industry pressures such as:

- . smaller cars,
- . higher percentage of imports,
- . automated diagnostics,
- . lower servicing requirements,
- . higher fuel prices,
- . high new car production quality.

The viability, profitability and growth of the companies and market channels assessed in this report are much more affected by their ability to foresee the expected changes than the changes themselves. The anticipated drop in total sales (1983-90) of 12% for spark plugs and 17% for exhaust products can be reduced by delaying the imposition date and possibly by informing the industry of the expected effects in order to allow them the maximum lead time to adapt to and hopefully avoid the potential impacts of the proposed regulations.

INVESTIGATION ON THE EFFECT OF FUEL TYPE AND COMPRESSION RATIO ON FUEL CONSUMPTION*

March 31, 1981

* This report was prepared for Environment Canada by Hickling-Partners Inc. under a Supply & Services Canada contract.

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This study was commissioned by the Policy, Planning and Analysis Directorate of the Environmental Protection Service in support of a socio-economic impact assessment of the further reduction in the allowable lead content in gasoline. The objectives of this study were:

- . to compare fuel consumption of vehicles requiring leaded fuel to those requiring unleaded fuel;
- . to assess the relationship of vehicle weight to fuel consumption differences between "leaded" and "unleaded" vehicles; and
- . to investigate the actual fuel consumption benefits achieved by increased compression ratios of engines.

By way of background to this study, it should be mentioned that currently there are two major methods of controlling vehicle emissions: by using an oxidizing catalyst and by complete in-engine control. The use of a catalyst is virtually required to meet the lower 1981 U.S. emission standards of 0.25 g/km for Hydrocarbons (HC), 2.1 g/km for Carbon Monoxide (CO) and 0.63 g/km for Oxides of Nitrogen (NO_x). Canadian standards for 1981 which are 1.2 g/km, 15.5 g/km and 1.9 g/km for HC, CO and NO_x respectively, allow the automobile manufacturer the option of controlling the emissions with and without the use of catalyst technology. However, in the 1980 model year, 80% of all cars sold in Canada used catalyst control technology. In 1981, this penetration rate appears to be approximately the same.

The use of oxidation catalysts imposes a requirement for the use of a fuel which does not contain tetraethyl lead or its accompanying halide scavengers as these elements "poison" the catalyst and thus render the catalyst less efficient. This requirement for unleaded fuel also imposes a fuel cost penalty on the consumer (3-4¢/L). However, due to the theoretical capability to optimize the engine for fuel consumption while allowing the emission control to be handled by the catalytic converter, there is a potential for catalyst-equipped vehicles to obtain lower fuel consumption than their non-catalytic opposites due to the decreased demands for in-engine emissions control.

While the possibility of fuel consumption sensitivity to control systems is real, no comprehensive comparative analysis of the vehicles actually offered to the consumer has been undertaken. Thus, this study was formulated in order to develop this assessment of the actual impact of the selection of control strategies on fuel consumption.

The results of the analysis of fuel consumption achieved by matched pairs of vehicles in which fuel type (emission control technique) was the principal variable indicated the following:

1. A comparison of Canadian pairs of vehicles, one lead-free, the other leaded, showed that when the engine is larger than 3.1 litres, and was designed more than 4 years ago, the lead-free vehicles had significantly lower fuel consumption than their leaded twin.
2. There is no significant difference in fuel consumption between catalytically controlled vehicles in the USA and Canada.
3. A comparison of 1980 and 1981 Canadian cars using leaded gasoline with 1980 and 1981 U.S. cars using catalytic converters and lead-free gasoline showed that neither group had a fuel consumption significantly different from the other.
4. For the European cars analysed, there was no statistically significant correlation between the changes in fuel consumption in relation to changes in compression ratio, and vehicle weight.

**COMPARISON OF FUEL CONSUMPTION BETWEEN VEHICLES EQUIPPED TO USE
LEADED AND UNLEADED FUELS***

March 1981

* This report was prepared for Environment Canada by Davis Engineering Ltd., under a Supply & Services Canada contract N° OSS 80-00222.

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This study was undertaken for Environment Canada to determine the relative differences in fuel consumption ratings of vehicles using unleaded and leaded fuel for matched parameters. The primary source of information for the study was the "Transport Canada Fuel Consumption Data", 1977-1981. The major Canadian automobile manufacturers were also to be contacted to get their views on future developments on unleaded and leaded fueled vehicles.

This report outlines the steps that were taken to accomplish the above objectives and present the results. The fuel consumption data was analysed utilizing a computer program to sort the data into a usable form and to calculate mean values for vehicles with similar parameters. The data was presented in tabular and graphical forms using the following methods of classification for unleaded and leaded fueled vehicles:

- (a) fuel consumption as a function of inertia weight only;
- (b) fuel consumption as a function of inertia weight with transmission and fuel supply systems matched; and,
- (c) fuel consumption as a function of inertia weight for matched vehicle pairs.

The analysis of the data showed that, as a general trend, there is a fuel consumption benefit for unleaded fueled vehicles which is especially apparent in the higher inertia weight categories. Another trend that was apparent was that vehicles manufactured in 1981 had a lower fuel consumption rating than in previous years investigated in the study.

From the replies of the major automobile manufacturers, it is apparent that General Motors and Ford are presently committed to manufacturing vehicles using unleaded fuel, while Chrysler is continuing to produce leaded fueled vehicles in the lower inertia weight categories.

The first and foremost of the reasons for the failure of the project is the lack of a clear and concise statement of the project's objectives. The project was initiated in 1970, but the objectives were not clearly defined until 1975. This led to a lack of direction and a failure to achieve the project's goals. The project was also hampered by a lack of resources, both in terms of personnel and equipment. The project was initiated in 1970, but the resources were not available until 1975. This led to a delay in the project's progress and a failure to achieve the project's goals.

The project was also hampered by a lack of communication. The project was initiated in 1970, but the communication was not clear until 1975. This led to a lack of coordination and a failure to achieve the project's goals. The project was also hampered by a lack of funding. The project was initiated in 1970, but the funding was not available until 1975. This led to a delay in the project's progress and a failure to achieve the project's goals.

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**GASOLINE FUEL SAVINGS IN CANADA AS A RESULT OF USING LEAD FREE
GASOLINE IN CARS***

October 1981

* This report was prepared for the Environmental Protection Service, Fuel Division, Environment Canada by Davis Engineering Ltd., under a Supply & Services Canada contract N° OSS81-00091.

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In a previous study undertaken for Environment Canada (1), it was found that the fuel consumption rates of unleaded fueled cars, particularly in the higher inertia weight categories, were lower than those vehicles consuming leaded fuel. In order to determine how these differences in fuel consumption rates have (or could have) influenced the overall fuel consumed by cars across Canada in the past few years, the present study was undertaken.

The overall objectives of the present study were two-fold:

- Determine the inertia weight distributions of cars in Canada as a function of year of manufacture for the years 1975 to 1981 and for the two fuel types.
- Determine the actual and potential fuel savings for cars in Canada for the years 1975 to 1981 through the use of lead-free gasoline.

Because the data used in the analyses, in some instances, were not completely available, this necessitated assumptions to be made which potentially caused error. These, however, would unlikely be so significant as to drastically change the findings of the study.

The major findings were as follows:

- (i) For the years from 1975 through to 1981, the trend was to go to lighter weight vehicles and to switch from leaded to unleaded fueled vehicles.
The average weight of the new cars decreased from 1 860 kg (4 090 pounds) in 1975 to 1 425 kg (3 135 pounds) in 1981, a decrease of 23%. Moreover, unleaded fueled vehicles weighed 30% more than leaded fueled vehicles, ranging from 19% in 1975 to 40% in 1980.
- (ii) Since in general, fuel consumption tends to increase with vehicle weight and because unleaded vehicles weigh more than leaded vehicles, this had the effect of increasing the fuel consumption of unleaded vehicles compared to leaded vehicles.
- (iii) Based on an assumed yearly kilometrage accumulation per vehicle of 16 000 km, the following were found through the use of lead-free gasoline.
 - the actual and potential calendar year fuel savings (savings in a given calendar year by the complete vehicle population existing in that year, e.g., year 1977

would include 1975, 1976, and 1977 vehicles) increased substantially from 1975 to 1980, but the rate of increase declined after 1978 for actual savings and from 1975 onwards, for potential savings. This trend resulted from more unleaded fueled vehicles in the population with each year from 1975 on.

- if all manufacturers had switched to unleaded fueled vehicles in 1975, by the end of 1981 further savings of 1.41 billion litres of fuel could potentially have been realized on top of the 3.08 billion litres realized in actual savings. For the total consumption of 46.16 billion litres, this represents actual savings of 6.3% and potential savings of 3.0%.

A SUMMARY PREPARED IN ENVIRONMENT CANADA OF THE PILORUSSO RESEARCH ASSOCIATES' STUDY ON "FORECAST DEMAND FOR GASOLINE"

February 1983

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- * This report was prepared for Environment Canada by Pilorusso Research Associates Inc., under Supply & Services Canada contract N° OSS81-00197.

The principal objective of this study is to estimate the future sales of motor fuel to year 1990, distributed by grades of gasolines. For this purpose, several factors were considered, including the size of Canadian fleet of passenger cars, light trucks and commercial vehicles; the age of the gasoline fleet; the state of engine technology; the fuel efficiency of the fleet; and the average annual mileage per vehicle.

It was assumed that under the high gasoline requirement scenario (prepared by Energy, Mines and Resources, December 1980), 1986 demand is roughly equal to 1979 base year requirements, and under the low scenario (prepared by Ethyl Corporation, 1981) about 18% below 1979 levels. Thus the 1979-based models constructed for petroleum refining and product distribution will reflect the gasoline requirements for 1986, the first year when any legislative changes regarding lead additives in gasoline would come into effect.

There were 12 million gasoline-powered vehicles in the Canadian fleet in 1979, including some 9.5 million passenger cars and 2.5 million other vehicles. With an anticipated growth rate of only 2-3% through the 1980's, the fleet size is expected to total 15 million vehicles in 1990. This naturally leads to increases in the demand for gasoline. Fuel efficiency is primarily dependent on the average age of the fleet and its vehicle size composition. The fleet fuel efficiency is anticipated to improve from 17.75 mpg in 1978 to 26.28 mpg in 1990, largely on account of the mandatory "corporate average fuel economy" regulation in the United States (e.g., 27.5 mpg for 1985). No reliable statistics exist on the average mileage of the Canadian fleet; but any real rise in the price of gasoline (offset by real increases in income level) will reduce the average mileage.

Notwithstanding research principally conducted in West Germany with a view to improving fuel efficiency (e.g., increasing the engine compression ratio and optimizing ignition timing), the consultant assumed that the required octane quality of gasoline will not materially change during the period under review. At present regular gasolines have a 92 RON and the premium grades a 96 RON.

In order to reduce emission levels of hydrocarbons, carbon monoxide and nitrogen oxides, the majority of new vehicles produced for the North American market is and will continue to be equipped with a catalytic converter, which requires unleaded fuel.

Up to 99% of the 1990-model vehicles is expected to be tolerant to unleaded gasoline, and an estimated 76% of the fleet will require unleaded fuel. On the subject of fuel economy comparison between leaded and unleaded vehicles, available studies have found no significant difference. The desire for increased fuel economy will lead to compression ratios higher than the present 8.5:1, which in turn will require fuel with a higher octane quality. The net result of these various factors is that over the next decade the demand for leaded gasoline is expected to fall.

Based on differing assumptions (e.g., percentage of catalytic-equipped vehicles, rate of scrappage and misfuelling), estimates of the leaded share of projected total fuel consumption of 223.9 million barrels in 1990 of 29% and 40% have been advanced respectively by DuPont and Ethyl Canada.

AN ANALYSIS OF THE ESTIMATED COSTS AND BENEFITS OF LEAD TRAPS RELATIVE TO CONVENTIONAL MUFFLER SYSTEMS*

November 1982

* This report was prepared for Environment Canada, by Pilorusso Research Associates Inc. under a Supply & Services Canada contract N° OSS81-00235.

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The purpose of this report is to determine the incremental costs and benefits to Canadian society of replacing conventional automotive muffler systems with lead traps, for those vehicles designed to run on leaded fuel. Lead traps prevent the lead from gasoline that is not burned in the combustion process from entering the atmosphere and are one of a series of possible methods of dealing with lead in gasoline being considered by the federal government. Given the lead times required for changes in the relevant regulations and to allow the time required for manufacturers to adjust to the new regulations, the costs and benefits of legislating compulsory use of lead traps have been calculated beginning in 1986 and ending in 1995.

The basic components of the analysis are:

- . Forecasted sales of vehicles using leaded gasoline, beginning in 1986.
- . Incremental costs (or savings) of lead trap systems over conventional mufflers.
- . Expected level of reduction in lead emissions as a result of the use of lead traps.
- . Expected benefits resulting from the reduction in lead emissions.

Summary of Major Conclusions

The major conclusions of the study are:

- . Automobiles designed to use leaded gasoline are estimated to account for approximately 20 percent of future car sales while light trucks designed to use leaded gasoline will represent approximately 5 percent of that market.
- . The life cycle costs of lead traps are lower than for conventional muffler systems, resulting in a savings to Canadian consumers if lead traps are used.
- . The use of lead traps would result in significant reductions of lead emissions although there is no evidence that such a reduction would result in any significant health benefits to Canadians.

Layout of the Report

Section two of the report deals with the development of forecasts of vehicle sales in Canada and a forecast of sales of vehicles designed to run on leaded gasoline.

In section three the differential costs of conventional muffler systems and lead traps are developed.

In section four the potential reduction in lead emissions and the resulting benefits are discussed.

**EFFECTS OF REDUCTIONS IN THE LEVEL OF LEAD ADDITIVES IN GASOLINE:
INCREMENTAL DISTRIBUTION COSTS***

June 1981

* This report was prepared for the Environmental Protection Service, Environment Canada by Peat, Marwick and Partners under a Supply & Services Canada contract N° OSS80-00172.

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The purpose of the study is to "determine the change in costs of distributing gasoline to Canadians as a result of eliminating the sale of leaded gasoline in Canada".

MAIN CONCLUSIONS

- . No change in the level of gasoline inventories and hence inventory carrying costs at refineries and bulk terminals would be expected as a result of eliminating the sale of leaded gasoline in Canada. Inventory levels are based on strategic considerations rather than the economies of distribution, and are, in fact, substantially in excess of distribution requirements.
- . No change in retail distribution costs (delivery and inventory carrying costs) would be expected as a result of eliminating the sale of leaded gasoline in Canada.
- . The continuation of three grades of gasoline, leaded, unleaded, and premium unleaded, might require extra tankage. The costs of this extra tankage could be saved by the early elimination of leaded gasoline.

BACKGROUND

Lead in the environment has been a longstanding concern because of its potentially harmful effects on human health. About 65% of total atmospheric lead results from the combustion of leaded gasoline. Consequently, the Federal Government is considering two levels of control of lead additives in gasoline:

- a) Reduction to 2 grams per imperial gallon
- b) Complete ban on lead additives to gasoline.

These two policy options would have impacts on various sectors such as lead producers, autoparts manufacturers and oil refiners and distributors. In the case of oil refining, the two options above would result in different amounts of capital investments in refinery facilities. In terms of distribution of finished gasoline products, only option b) results in a structural difference: that is, elimination of lead additives would decrease the number of gasoline products now being distributed to consumers.

Generally speaking, three products are now marketed in Canada: unleaded premium, unleaded regular, and leaded regular gasoline. (In some areas, small amounts of leaded premium are still being sold.) The policy option b) means a change in distribution patterns to two products instead of three. This report examines the potential impacts on distribution costs as a result of the elimination of one grade of gasoline. The distribution cost items considered include:

- . inventory carrying costs
- . operating costs of distribution
- . capital investment
- . administrative costs

APPROACH

This study utilized three main approaches:

- . analysis of published data
- . detailed interviews with:
 - senior and operating management of five major oil companies
 - officials of other relevant organizations
- . development of models to simulate behaviour under both three product and two product systems, using the first two approaches as inputs.

The interviews and published data resulted in an Industry Overview (Chapter I) which describes the physical distribution system for motor gasoline in Canada, including regional variations.

Primary Distribution, from refineries to bulk distribution terminals is analyzed in Chapter II, with a focus on actual versus required gasoline inventories, and adequacy of existing terminal storage tanks.

Secondary Distribution (marketing), from terminals to service stations is analyzed in Chapter III. A computer model was used to simulate required service station deliveries and inventories for scenarios consisting of three products and two products.

Chapter IV deals with potential administrative and equipment cost savings and various other matters such as anticipated future service station closures, and reasons for the price differential between leaded and unleaded regular gasolines.

SUMMARY OF FINDINGS AND CONCLUSIONS

Industry Overview

Physical distribution of motor gasoline is generally organized according to Primary Distribution (refineries to bulk distribution terminals) and Secondary Distribution or marketing (terminals to service stations). Approximately 85% of inventories are held in the Primary system, while about 15% are held in the Secondary system at service stations.

Primary Distribution involves transportation of large quantities of gasoline from refineries to terminals by either pipeline, or ship or rail. In cases where refineries are located close to population centers such as Vancouver, Toronto and Montreal, the first movement is usually by truck, direct to service stations. The importance of the modes of transportation varies widely according to geographic and population location considerations. Pipeline movements are very important in the Prairies and Central Canada, while ship and rail movements are relatively more important in British Columbia and the Atlantic provinces.

Secondary distribution from terminals to service stations is carried out by tank trucks. To the extent possible, the largest possible truck is used, the size being limited by provincial weight restrictions. Due to high costs of labour and equipment, priority is given to optimizing trucking efficiencies.

In 1979, there were approximately 24 000 retail outlets whose main activity was sales of motor gasoline. The five largest integrated oil companies account for about 70% of these retail outlets.

Seasonality of Sales and Inventories

Sales of motor gasoline peak in the month of August and are lowest in February. The peak sales are about 20% higher than average monthly sales. Inventories

on the other hand are highest in March and lowest in October. Seasonal inventories are held mostly at the refineries, with a little at some terminals, but none at the retail pumps.

Middle distillates and gasoline are produced simultaneously during the refining process. Middle distillates sales (including heating oil) are counter-seasonal to those of gasoline. Thus, to a certain extent, seasonal inventory accumulations of each product are a reflection of production demands for the other products.

Trends in Gasoline Sales

Unleaded gasoline was first introduced in Canada in 1974. There has been a rapid increase in the percentage of unleaded regular gasoline to total regular gasoline sales since then, as automobiles requiring unleaded fuel enter the fleet, but essentially only automobiles using leaded gasoline leave the fleet. This rapid increase is anticipated to continue to about 1985, when the cars requiring unleaded gasoline also begin to leave the fleet in substantial numbers, based on an average life of 10 to 11 years. Total gasoline sales are expected to peak in 1982-1983 and decline slowly thereafter.

The switch to unleaded regular gasoline has however, been much slower in the four Western provinces. The reasons include longer average vehicle life and a higher proportion of vehicles not requiring unleaded gasoline. The share of premium gasoline sales has remained stable in Ontario, Quebec and Prince Edward Island, but has declined elsewhere.

Potential Changes in Primary Distribution Costs

Our analysis has shown that the usual safety stock rules for inventory management do not govern the levels of inventories at the refineries and terminals. The estimated inventory requirements based on these rules vary regionally across Canada from 4 days supply in the West to 12 days in the Atlantic provinces. The actual days supply varies correspondingly from 15 to 42 days supply with a total national supply of 26 days. The reasons for these inventory levels are:

- 1) Inventories are built up for strategic considerations involving security of national supply.
- 2) The oil companies move gasoline to the terminals to provide increased buffers against stockouts.
- 3) International agreements require an inventory of about 22 days supply.

We thus conclude that no primary inventory level changes would result if only two products were sold and hence no inventory carrying cost differentials would be experienced.

We further investigated the impact on terminal tankage requirements for the rapid increase in the proportion of unleaded regular gasoline sales. At some terminals with only one tank per product, the tankage would currently be "tight", so that by 1983 or 1984, a significant mis-match could develop between demand and tankage configurations, resulting in requirements for additional unleaded tank facilities. This situation will tend to correct itself in some areas (Eastern Canada) as the proportion of unleaded gasoline continues to grow and eventually becomes the same as the original proportion of leaded gasoline. Then the tankage could simply be reversed. In Western areas, the mis-match would be more likely to persist, since the split of unleaded to leaded gasoline will not reverse itself. We have estimated the annual equivalent of these capital costs to be about 0.1 cents per litre for a group of Eastern pipeline terminals.

These costs would be avoided with the elimination of one grade of regular gasoline so that the regular grade tankage could be combined. This would be a benefit of the proposed lead controls only if this regulation were enacted before 1983 or 1984. Otherwise, the tankage required would be already purchased.

Based on our understanding that no lead control legislation could be enacted before 1985, we conclude that no tankage cost savings would be achieved.

Potential Changes in Secondary Distribution Costs

We built a service station model to simulate deliveries and inventories at service stations, based on priorities described during our industry interviews. These priorities involved:

- elimination of stockouts

- delivery of full trackloads
- inventories should not be less than a "target" level after delivery.

These decision rules result in a system in which inventories are maximized, rather than minimized. Consequently, given existing tankage, it was hypothesized that no changes in inventory levels would result if only two gasoline products were marketed instead of three products.

To test this, several typical service stations were modelled, with variations in annual sales, share by grade, tankage configurations, and delivery truck size. A comparison was made for the three product and two product scenarios:

- the delivery frequency
- stockouts
- inventory levels
- numbers of less than full-load deliveries.

Although slight differences were found in these indicators between the two scenarios, the average differences over the entire distribution system were so small as to be negligible. We conclude that the delivery and inventory carrying costs of the Secondary Distribution System would remain unchanged, except as described in the next paragraph.

By an argument similar to the above for terminal tankage, we conclude that some investment in tanks in the near term would be required. These could be deemed benefits of the proposed lead controls only if enacted by 1983-1984. Otherwise no cost savings could be achieved.

OTHER CONSIDERATIONS

Other Cost Savings

Based on industry interviews, we conclude that no cost savings could be achieved in equipment such as tanks or pumps or in administrative costs.

It should be noted that in a two gasoline product system, some of the service station pumps freed up (while not generally re-usable elsewhere) would be available as a channel of distribution for diesel fuel, thus providing increased access to diesel fuel for

those consumers with diesel engines. This could be counted as a benefit of the proposed regulation, in that diesel-powered vehicles are more fuel-efficient.

Price Differential for Unleaded Gasoline

The observed price differential between unleaded and leaded regular gasoline is made up of two components:

- increased crude oil feed stock costs per unit of output,
- willingness of consumers to pay for a differentiated product.

The latter provides an opportunity for the oil companies to maximize their profits on the one hand, and provides a lower priced product to a part of the market on the other.

Trends in Distribution

During the decade of the 1970's, there were significant numbers of service station closures as the result of:

- consolidation of marginal stations
- moves to larger suburban service stations
- switch to larger volume self-serve stations
- increased value of downtown urban real estate.

Most companies indicated that most of these closures are complete, and not more than a further 10% to 15% decrease would occur by 1990 for reasons of consolidation.

Some industry representatives indicated the possibility of two or more oil companies agreeing to jointly manage certain bulk terminals in order to avoid duplication of operating costs.

LEADED GASOLINE EXCISE TAX

December 1982

* This report was prepared for the Environmental Protection Service, Environment Canada, by Lavalin and Econosult Inc. under a Supply & Services Canada contract N° OSS 82-00084.

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Lead is a relatively cheap and useful substance in combination with other elements in a variety of industrial uses. One of those uses is in automotive gasoline. Additives containing lead have been used for many years to improve engine performance.

Unfortunately, automotive engine emissions containing lead are a major source of air pollution. Environment Canada has initiated a socio-economic impact analysis which is considering six alternatives for reducing lead emissions from automotive exhausts.

The capital requirements and subsequent operating cost of producing 100% unleaded gasoline, related to the projected revenue, could prove to be a major deterrent to the conversion of some or all refineries in Canada. Increasing emission control standards to completely eliminate the use of leaded gasoline could produce a serious adverse economic impact in Canada, particularly in view of the fact that four refineries in Eastern Canada have already been closed.

A possible alternative would be to discharge the use of leaded gas by means of an excise tax which could theoretically be adjusted to reduce the volume of leaded gas sold. The main difference between this proposal and one to tighten emission control standards to U.S. levels (with the resulting prohibition of cars without catalytic converters) is that the use of leaded gasoline need not be eliminated completely.

The purpose of this study is to develop a strategy to reduce the use of leaded gasoline in Canada to between 20% and 40% of total gasoline consumption by imposing a special excise tax on leaded gasoline in order to make its price approximately the same as the price of lead-free gasoline.

Section 2, Price-Demand Study, reviews the available literature and information provided by the Scientific Authority of Environment Canada. Statistics on the market in Canada for different grades of gasoline are also analyzed.

From this analysis, the following propositions can be made:

- 1) From the statistical evidence, the price differential between leaded and unleaded gasoline does not seem to have influenced the consumer's choice between grades or the ratio of unleaded/leaded gasoline sales.

- 2) If gasoline prices increase sufficiently, the consumer may try to maintain his previous level of consumption and expenditures by converting to a lower priced grade.
- 3) Volumes sold in provinces where the ratio of unleaded to leaded gasoline is highest (i.e., in Quebec and Ontario); and in provinces where the ratio is lowest (i.e., Saskatchewan and Alberta); indicate that the price cross-elasticity of demand between grades may be low or nil.

These preliminary conclusions were confirmed by a detailed analysis of price/volume relationships during and after a price war when costs per litre and price differentials varied considerably and rapidly. Regression analysis confirmed that without change in other factors, the sales of unleaded gasoline would not increase if the price of leaded gasoline increased. Changes in the price structure of the two grades do not affect the demand for each grade.

A misfuelling survey and a questionnaire sent to car manufacturers also supported these findings.

The Price-Demand study also demonstrated that in view of the divergent price differential across Canada, a tax to reduce the differential but not to remove it altogether could not be the same percentage, or the same number of cents per litre, across the country. A tax imposed by provincial authorities, designed to reduce but not remove the price differential separately in each province, would involve many complicated calculations. Also, if successful in reducing sales of leaded gasoline, it would fall disproportionately on Western Canada.

Section 3, Policy Strategy, examines the relative merits of the excise tax and regulatory options in terms of their likely effectiveness and efficiency. Present price setting mechanisms are examined in detail and the possible reactions of refineries and gasoline distributors to market changes are described, with and without the imposition of an excise tax or new regulations.

Three expectations follow from this analysis:

- an excise tax will be passed on to the consumer to the maximum possible extent, dependent on elasticity of demand and competitive activity;
- an excise tax increase will probably be accompanied by an increase in price which will accrue to the distributor;

- it will be difficult if not impossible to isolate the precise effects of a percentage or cents per litre tax on the selling prices at the pump of the grades concerned.

Direct price regulation does not appear to be feasible. If the regulated price is set above the market clearing price the oil companies would initially make wind fall profits but surpluses would develop. To maintain the regulated price at an artificial level it would be necessary for the government to regulate volumes of output of the various refineries. This would require that the regulators possess much greater knowledge of the firm's technologies (and of the changing markets) than is likely to be the case.

The conclusions derived from Section 2 and 3 of this study confirm that an excise tax remains a feasible strategy, providing means could be found to maintain it, and the selling prices at the pump, at a predetermined level. However, in view of the finding that cross-elasticity between the grades is negligible, and for other reasons, it is not expected that an excise tax can be used by the Government as an instrument of fine tuning, especially while the price of leaded gasoline remains lower than the price of unleaded gasoline.

In view of these negative findings, Section 4, Gasoline Demand Scenarios, and Section 5, Benefit-Cost Analysis based on selected demand scenarios, are conducted on the following two assumptions:

- 1) A tax will be imposed to create the same pump price for leaded gasoline as for unleaded gasoline.
- 2) A tax will be imposed to create a higher pump price for leaded gasoline than for unleaded gasoline.

The results of this benefit-cost analysis using a discount rate of 10% are as follows:

The benefit-cost ratio (including capital costs) of

- (1) Equal Price Scenario is 0.75 (minimum effect assumptions) and 0.58 (maximum effect assumptions).

Benefit-cost ratio (including capital costs) of

- (2) Higher Price Scenario is 0.58 (minimum effect) and 0.55 (maximum effect).

Benefit-cost ratio (excluding capital costs) of

(1) Equal Price Scenario is 0.89 (minimum effect) and 0.66 (maximum effect).

Benefit-cost ratio (excluding capital costs) of

(2) Higher Price Scenario is 0.66 (minimum effect) and 0.64 (maximum effect).

Using discount rate of zero, 5% and 15% does not affect these results significantly.

The conclusion is that the objective of 60% to 80% levels of unleaded gasoline should be reached if the price of leaded gasoline were to be set equal to the price of regular unleaded gas or slightly higher.

Moreover, the 70% level would probably be reached merely with the two prices being set equal.

The net total costs (including capital costs) of obtaining a 70% to 73% unleaded level by 1990 would be about 260 million 1979 dollars actualized to the year 1985 at a discount rate of 10%. The average net cost (not actualized) would be about 30 million 1979 dollars per year for the period 1985 to 1995.

However, these results are all based on the assumption that additional capital and operating costs will in any case be incurred by the refineries to increase the present proportion of unleaded gasoline to total gasoline (40.4% in 1981 to 60.0%) by 1990. The net total cost calculated above does therefore not represent the full additional payment to be made by gasoline users to reach the 70-73% unleaded level. It is the incremental cost of increasing from the 60% level.

The analysis is also based on the assumption that means would be found to ensure that the price of leaded gasoline at the pump would remain at or above the price of unleaded gasoline. The study illustrates the fact that this assumption is open to serious question.

**ASSESSMENT OF PARTIAL REDUCTION IN LEADED GASOLINE POOL ON REFINERY
CONSTRUCTION COSTS***

December 1982

* This report was prepared for the Environmental Protection Service, Environment Canada, by MHG International Ltd. under Supply & Services Canada Contract N° 52SS KE145-2-0421.

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As part of its ongoing efforts to improve the quality of the Canadian environment, the Environmental Protection Service of Environment Canada wished to determine the effects upon the petroleum refining industry of reducing the quantity of lead antiknock additives in motor gasoline.

MHG International was commissioned to undertake three related studies (Ref. 1, 2 and 3), the principal objectives of which were to define the extra processing capacity required across Canada for various gasoline production schedules and with various amounts of lead antiknock additive removed. In addition to requiring extra processing capacity, the removal of lead antiknock additive from gasoline, while at the same time retaining its octane rating, requires the processing of additional crude oil for the same quantity of gasoline produced.

The base case used in all of the studies was the actual conditions that existed in the year 1979 in which about 37.5% of the total gasoline produced was lead-free. One of the cases studies in Ref. 1 represented a totally lead-free case and showed that a considerable capital expenditure would be involved.

In this study, MHG presents two additional cases between these two extremes, namely the production of lead-free gasoline amounting to 70% and 82% of the total produced in 1979.

A SUMMARY PREPARED IN ENVIRONMENT CANADA OF THE H.M.W. & ASSOCIATES LTD. REPORT "AN EVALUATION OF THE POTENTIAL HUMAN HEALTH CONSEQUENCES FROM LEAD IN GASOLINE IN CANADA"

THESE RESULTS ARE IN ACCORD WITH THE FINDINGS OF OTHER STUDIES
WHICH HAVE SHOWN THAT THE INCIDENCE OF THIS DISEASE IS
HIGHER IN THE NORTH THAN IN THE SOUTH.

The potential impact on the health of Canadians of lead from gasoline is assessed. The direct sources of human lead exposure are from food, water and air, with the ultimate entry into the body via the mouth and lungs. The quantity of lead dispersed into the Canadian environment was about 19 340 tons in 1970, of which lead emissions from leaded gasoline were 14 000 tons or about 72.5%. These lead emissions decreased by 2.8% annually or 10 900 tons by 1978, due primarily to the expanded use of lead-free gasoline.

Exhaust from the automotive engine fuelled with leaded gasoline contributes substantially to the lead levels in the atmosphere and in street dirt and dust, the latter being a significant source of blood lead levels in urban children. The contribution, however, of leaded gasoline to the lead intake through food and drinking water is thought to be small.

To evaluate the impact of lead on health, it is essential to understand the relationship between lead intake and the effects of lead adsorption into the body. In most cases of human exposure, however, the actual level of lead intake in which the effects are assessed is not known. Lead levels in blood thus have been used to indicate the magnitude and recent history of lead intake, as blood samples are easily obtained and reliably analyzed for lead content.

In sum, the contribution of leaded gasoline to the total lead intake of Canadians would appear to range from 22% for adults to some 57% for children. The estimated lead exposure, however, is generally below the level of lead intake proven to result in adverse effects on human health. Accordingly it cannot be concluded that a reduction in the concentration of lead in gasoline would significantly improve the health of Canadians. As there is evidence, however, that children may be exposed to much higher than normal levels of lead, or may be susceptible to lead and suffer from behavioural and possibly adverse biochemical effects as a result of lead intake, the concentration of lead in gasoline should be limited until a clearer understanding of its impact, if any, on possible susceptible population groups becomes available from research currently in progress.

R *Canada: S. of E.* *M.C.T. II*

AUTHOR <i>EN S. CONSULTANT STUDIES</i>		
TITLE <i>RELATED TO LEAD MAKE-DOWN</i>		
DATE DUE	BORROWER'S NAME	DATE RET'D

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